DECK BOXES FOR UHF SATCOM RADIO FREQUENCY INTERFERENCE STUDY

Gary Brent Parker

NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

DECK BOXES FOR UHF SATCOM RADIO FREQUENCY
INTERFERENCE STUDY

by

Gary Brent Parker

June 1976

Thesis Advisor: John E. Ohlson

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)

DECK BOXES FOR UHF SATCOM RADIO FREQUENCY INTERFERENCE STUDY

5. TYPE OF REPORT & PERIOD COVERED

Master's Thesis; June 1976

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)

Gary Brent Parker

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS

Naval Postgraduate School
Monterey, California 93940

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS

Naval Postgraduate School
Monterey, California 93940

12. REPORT DATE

June 1976

13. NUMBER OF PAGES

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

Naval Postgraduate School
Monterey, California 93940

15. SECURITY CLASS. (of this report)

Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report concerns itself with the design, construction, and utilization of a remotely controlled deck box assembly. This deck box assembly was used in conjunction with other specialized equipments for the study of radio frequency interference. This study,

Deck Boxes for UHF SATCOM Radio Frequency Interference Study

by

Gary Brent Parker
Lieutenant, United States Navy
B.S., University of Washington, 1969

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

from the

NAVAL POSTGRADUATE SCHOOL
June 1976

ABSTRACT

This report concerns itself with the design, construction, and utilization of a remotely controlled deck box assembly. This deck box assembly was used in conjunction with other specialized equipments for the study of radio frequency interference. This study, "Shipboard RFI in UHF SATCOM," was sponsored by the Naval Electronics System Command and concerns itself with the electromagnetic spectrum and potential RFI in the 240 to 400 MHz band. These deck boxes incorporate fixed and tunable bandpass filters, tunable notch filters, remotely controlled coaxial switches, an amplifier, attenuator, and noise diode in an RF protected enclosure. Details include design criteria, component selection, circuit construction, physical layout, control circuitry and technical support for the deck box assembly.

TABLE OF CONTENTS

I. INTRODUCTION

A study was undertaken to characterize shipboard radio frequency interference (RFI) in that portion of the ultra high frequency (UHF) band assigned for satellite communications (SATCOM), 240-400 MHz. This investigation was comprised of many individual parts and this report deals with the design, construction, testing and use of the deck boxes. The deck boxes and their associated control box were used aboard various ships of the U.S. Navy to determine the characteristics and severity of RFI in the UHF SATCOM band.

The initial test equipment developed and constructed at the Naval Postgraduate School consisted of a complete test apparatus to evaluate RFI in the SATCOM band. This equipment consisted of five subsystems, four of which were constructed specifically for this project. The first was the deck box, the purpose of which was to accept the signal from the test antenna, filter it as necessary, provide a reference noise level for system noise measurements, amplify the signal, and send the signal via coaxial cable to the RF and IF amplifier subsystems. This report concerns itself with the design and construction of the two deck boxes and associated control circuits and cabling. The RF and IF subsystems [1,2] further conditioned this signal before applying it to the amplitude density analyzer, [3] the fourth subsystem, and the spectrum analyzer, the fifth subsystem.

II. DESIGN CRITERIA

As initially envisioned, the deck boxes were to consist of a bank of contiguous filters which were to be remotely selectable (See Figure 1). These fixed filters were to be used for the purpose of isolating a small band of frequencies in order to reduce saturation and intermodulation products within the band of interest. Also envisioned were a noise diode for system calibration purposes, and an RF amplifier to raise the filtered signal to a level suitable for transmission via coaxial cable to the other elements of the system.

The entire deck box assembly was to be physically constructed such that it could withstand the severe environmental conditions encountered on the weather deck of an operational vessel. This was envisioned as requiring sealing against radio frequency interference as well as salt water, rain, fog, heat and cold. The deck boxes were to be remotely controllable from the main test console and a complete backup control system was desirable within the deck boxes for local control of all functions. A bypass mode for the RF circuitry was desirable in order to be able to look at a broad RF spectrum (See Figure 1).

II. DESIGN CRITERIA

As initially envisioned, the deck boxes were to consist of a bank of contiguous filters which were to be remotely selectable (See Figure 1). These fixed filters were to be used for the purpose of isolating a small band of frequencies in order to reduce saturation and intermodulation products within the band of interest. Also envisioned were a noise diode for system calibration purposes, and an RF amplifier to raise the filtered signal to a level suitable for transmission via coaxial cable to the other elements of the system.

The entire deck box assembly was to be physically constructed such that it could withstand the severe environmental conditions encountered on the weather deck of an operational vessel. This was envisioned as requiring sealing against radio frequency interference as well as salt water, rain, fog, heat and cold. The deck boxes were to be remotely controllable from the main test console and a complete backup control system was desirable within the deck boxes for local control of all functions. A bypass mode for the RF circuitry was desirable in order to be able to look at a broad RF spectrum (See Figure 1).

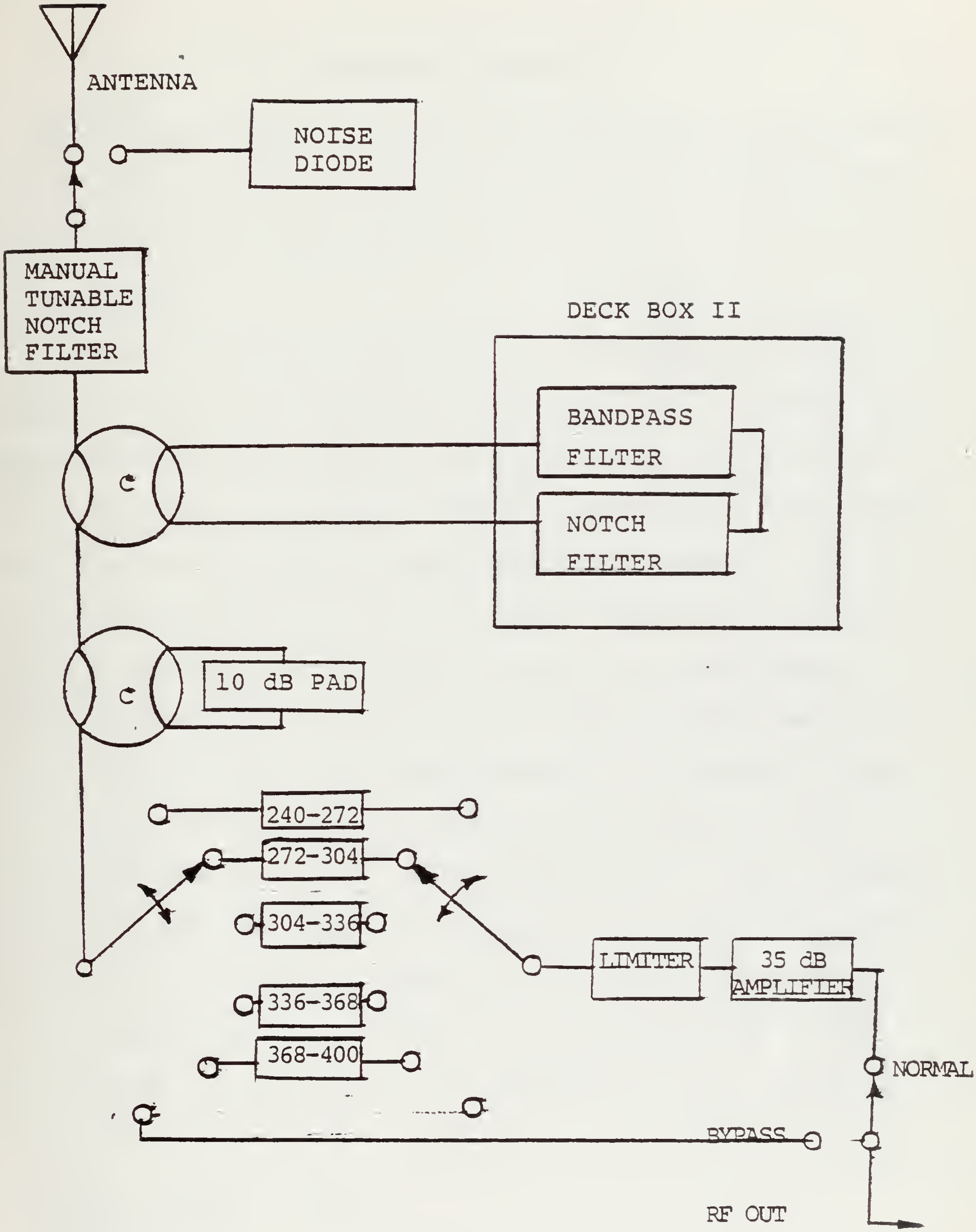

Figure 1. DECK BOX BLOCK DIAGRAM

III. COMPONENT SELECTION

Before construction of the deck boxes began, it was necessary to carefully select the major element to be used within the two deck boxes and control box.

A. DECK BOXES

The first items selected were suitable boxes in which to package the deck box components. They had to be rugged, preferably steel, fairly compact, and capable of being sealed against water, salt, humidity and RF interference. Two boxes were purchased from the Hoffman Electrical Company. The A-1614CH RFI measuring 16 x 14 x 6 inches came with a factory-installed weatherproofing gasket as well as an RF gasket specified at 100 dB of isolation at 1 MHz for both magnetic and electric fields. The boxes featured a continuous hinge down one side of the lid and substantial clamping devices around the remaining three sides of the cover. This clamping arrangement and the gasketing consisting of a neoprene rubber strip for environmental protection and a metallic mesh strip for RFI protection allowed the box to be opened and closed many hundreds of times without degradation to the gasketing material or the protection offered.

B. FIXED BANDPASS FILTERS

Specifications for the bandpass filters were next prepared. These filters were to cover the frequency band of interest, 240 to 400 MHz, in five equal steps. Insertion loss was to be less than 1.5 dB, and the VSWR was not to exceed 1.5 within

the 32 MHz bandwidth. An average power handling capability of 150 watts was specified with peak power capability of 5,000 watts. All were to be sealed to withstand relative humidities of 95 percent and to be operational from -20°C to +50°C. Each filter was to have 1 dB bandpass of 32 MHz with the passband down a minimum of 70 dB at ± 44 MHz from the center frequencies. The following 1 dB bandpasses were specified.

240 MHz to 272 MHz

272 MHz to 304 MHz

304 MHz to 336 MHz

336 MHz to 368 MHz

368 MHz to 400 MHz

C. COAXIAL SWITCHES

Coaxial switches for remotely selecting the bandpass filter, switching the noise diode in and out of the circuit, and switching a tunable notch filter in and out of the RF circuit were next selected. A pair of single pole, six throw (SP6T) switches for filter selection were first selected. Five positions were used for the five fixed band-pass filters and the sixth in conjunction with a single pole, double throw (SPDT) coaxial switch was used as an RF bypass. A coaxial transfer switch was also ordered to insert a tunable notch filter into the RF circuitry. Another single pole, double throw switch was utilized to select the noise diode or the antenna as the input to the circuit. Specifications on all coaxial switches were such that they should have female

SMA fittings, operate on 24 to 28 volts, direct current and contain internal indicator circuitry. Latching switches were considered, but non-latching switches were deemed acceptable for economic reasons, and required fewer conductors in the control cable.

D. NOTCH AND BANDPASS FILTERS

Early consideration and calculations of potential interferers located on the fringes of the 240 to 400 MHz band indicated that some additional means of suppressing very strong interfering signals would be desirable. With the possibility of radars having peak power outputs up to 1 megawatt both immediately above and below this band and the probability of some of this power being coupled into the 240 to 400 MHz band, a tunable notch filter was selected. Two models of the notch filter were chosen. One covered 200 to 400 MHz and was used for suppressing radars in the 200 to 225 MHz band and the second covered 250 to 500 MHz for use with radars operating above 400 MHz. Both were of the same physical dimensions and capable of being interchanged within the deck box as appropriate for each ship. Both models had insertion losses of less than 0.5 dB and 20 dB bandwidths of 5 MHz. In addition to their above-stated application, they could also be utilized to suppress inband signals radiating from a UHF transmitter on board the ship.

The initial intention was to have this filter remotely switchable into the circuit when needed. However, later investigation of the tunable notch filters supplied indicated

G. NOISE DIODE

An Ailtech Noise Diode, Model 07615, was used as a standard noise source. This device was used for reference in the entire measurement system as a source by means of which the noise figure of the system could be calculated. It was important that this device be located at a point which was the input to the entire measurement system; therefore, it was decided to connect its output through a single pole, double throw coaxial switch with the other position being the antenna input. An accurate and stable 28 volt direct current source is required to power the noise diode.

H. 10 dB ATTENUATOR

Another feature of the deck box was a 10 dB attenuator which was remotely switched in and out of the circuit using a coaxial transfer switch. Signals not actually being received by the antenna, for example, internally introduced test or reference signals, or intermodulation products originating within the test equipment could mistakenly be analyzed and treated as external signals. By installing a 10 dB attenuator near the input to the system on a remotely controllable transfer switch, an easy verification of the origin of the signal could be obtained. If when the 10 dB attenuator was inserted, the observed signal decreased in power by 10 dB on the spectrum analyzer display, the observed signal was in fact a valid signal. If it did not change, an internally introduced signal such as the local oscillator or a reference signal was indicated. If the observed signal decreased by 20 dB or any

larger integer multiple of 10 dB, an intermodulation product generated within the test system was indicated.

I. POWER SUPPLY

The power supply for the system was selected with the thought in mind that very accurate voltages would have to be maintained at the input of such items as the noise diode and RF amplifier. Less critical voltages were required for the coaxial switches and local indicator circuitry. In order to supply the accurate voltages at varying distances from the main power source, in this case 110 volt alternating current, it would be necessary to regulate the critical voltages within the deck box itself. In addition, it was deemed unwise to send 110 volt AC up the control cable to the deck box due to cross-coupling of AC hum and the potential hazard to personnel.

1. Thirty-six Volt Supply

A thirty-six volt Acopian direct current power supply was used which had a 2.3 ampere output with 1.5 millivolt RMS ripple. The 36 volt level was sent from the main control box where the power supply was physically located to the deck box utilizing three 22-gauge conductors in the control cable. Using this method, the full load voltage drop along the length of a 200 foot control cable was less than 1.5 volts. To partially compensate for this loss, the output of the power supply was adjusted to its upper value of 36.5 volts and the worse case voltage at the input of the deck box became 35 volts. This represents a three volt safety margin over the 32 volts required for the deck box to function normally.

2. <u>Voltage Regulators</u>

Within the deck box are located three LAMBDA power hybrid voltage regulators, one each for the 28 volt, 24 volt and 5 volt DC outputs. The 28 volt regulator supplies the noise diode, all coaxial relays, and other relays in the deck box. The 24 volt regulator supplies the RF amplifier only, and the 5 volt regulator supplies voltages for all indicator circuitry. (See Appendix A). Overvoltage protectors supplied by Acopian were used at the output of each of the voltage regulators for protection of circuit elements due to a malfunction of any part of the power supply.

IV. DECK BOX CIRCUIT CONSTRUCTION

A. GENERAL LAYOUT

After assembling all of the components for the deck box, it was determined that the 16 x 14 x 6 inch steel boxes from Hoffman Electric Company could be used. The boxes came with four mounting studs welded to the bottom of the box and extending 7/16 inch into the box. In deck box I an aluminum plate 3/16 inch in thickness was cut to fit as a subchassis for all of the other components. (See Figure 2). To this were bolted the three voltage regulators, three overvoltage protectors, and a bracket to hold the five fixed bandpass filters. A plate was installed over the five bandpass filter to hold them in place and another aluminum box approximately 10-1/2 x 6-1/2 x 2-1/2 inches was screwed to this plate. Within this smaller box were all of the original coaxial switches, local control switches, LED indicators, relays and other components. The RF amplifier and limiter were mounted on the right top end of this smaller box and the noise diode on the left top end. As additions were made to the capability of the deck box, an additional transfer switch was mounted on the side of this box to control the 10 dB attenuator (See Figure 2).

B. RELAY CONTROL

It was desirable to have all control functions located at the main control box duplicated within the deck box. This was considered of importance for two reasons. First, in case

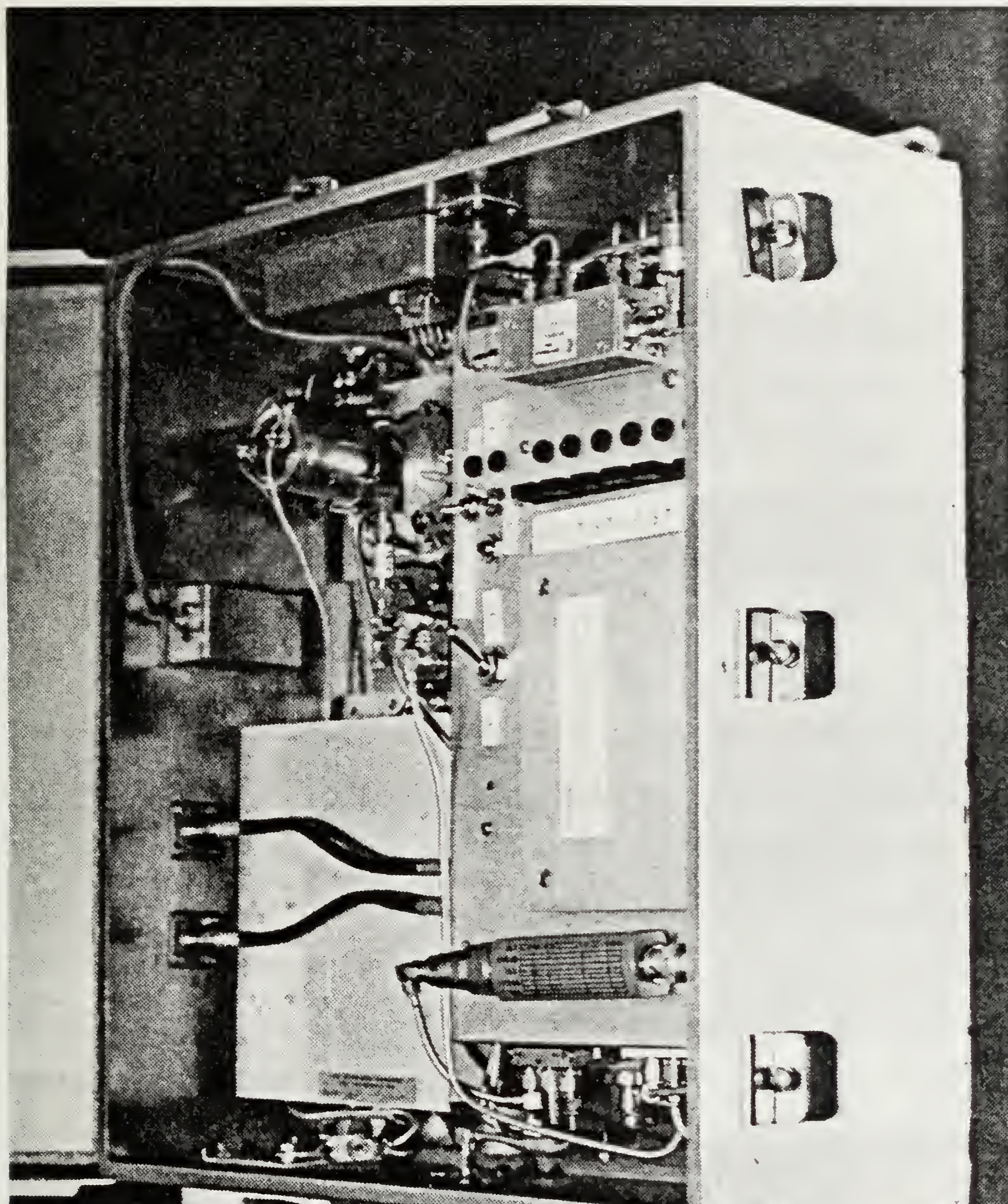

Figure 2. DECK BOX I, FRONT VIEW.

of malfunction of the control circuitry or failure of the control cable, it would be easy for the operator to go to the box and take manual control. Secondly, by having all controls at his fingertips, it made troubleshooting and fault location within the deck box considerably more straightforward.

Several design approaches to controlling the coaxial switches remotely were investigated. The first involved coding the six or eight separate channels to the deck box in a binary code and utilizing only three control lines. This proved feasible in the laboratory, but was judged overly complicated, more susceptible to interference, and less reliable than using a separate control line for each function. Therefore, a design effort was undertaken and implemented utilizing a 5 volt control signal at a very low current. This current, in the order of 2 milliamps, was used to turn the coaxial switches on and off via a solid state integrated circuit relay driver. Each relay required approximately 160 miliamperes at 28 volts for activation; therefore, a high voltage, high current Darlington transistor array produced by Sprague was selected. The ULN-2003A consists of seven drive circuits, each capable of sinking up to 500 miliamperes. For safety reasons, pairs of drivers were utilized to decrease the current in any one driver circuit. This approach was successful until control cables in excess of 200 feet long were attached to the circuit. At this point the integrated circuits began to fail. It was decided that transients traveling up and down the control line were at fault and this approach was

abandoned in favor of sinking the relay switching current directly down the control line. It was feared that this method might introduce undesirable transients into adjacent control lines; therefore, diodes were installed in the deck box for transient protection. This proved to work effectively and no adjacent wire interference was noted. These protection diodes also served as protection to the switches used to control the coaxial switches.

C. LOCAL/REMOTE CONTROL CIRCUITRY

An eight pole, double throw switch is located in the top of the relay box and is used to transfer control of the deck box from "Remote" to "Local." The local control switches are located to the right of this switch and their indicator LED's are immediately adjacent. In order to decrease the number of wires required in the control cable, the only indicator light on the front panel of the main control box is the RF continuity light that indicates when the two six-position coaxial switches are matched. If either of the six pole switches fails or goes to the wrong position, this light will not come on. With this arrangement it was not possible to tell which filter was selected but only that the input and output coaxial switches used for filter selection agree. However, the indicator circuitry within the deck box was capable of indicating which filter was in the circuit. Filter selection was accomplished by depressing any of the six-position interlocking switch buttons. Five buttons corresponded to filters and the sixth to the bypass mode. Two single pole, double throw switches

and LED indicators were also provided. The first was to switch from "ANTENNA" to "NOISE DIODE" and the second activates the transfer switch and connects the tunable notch and bandpass filters in the second deck box into the circuit. (See Figure 2)

A pushbutton was also included which, when pushed in the "ANTENNA" position, inserted the 10 dB attenuator in the RF path. When in the "NOISE DIODE" position, this same push-button turns the noise diode on.

D. RF SHIELDING

Radio frequency shielding of components located within the deck box from each other was not considered necessary. During the period when the relay drivers were utilized, an RF tight box was installed in the top of the relay box and the printed circuit board containing the drivers was isolated from the rest of the circuit by using feed-through capacitors. When the design was changed to its final configuration, this same box was used to house the transient protection diodes, but the RF shielding was no longer necessary.

The deck box itself had the requirement of shielding its components from very intense electromagnetic fields, e.g., radar near-field. The bare box affords an isolation of at least 100 dB from the surrounding environment but due to many perforations in the box for connectors a stringent policy of RFI shielding was observed. All leads including control and indicator circuitry first passed through a dog-box bonded to bare metal on the inside of the deck box (See Figure 2). This joint was sealed with an RF gasketing material. Within the

dog-box at least four ferrite beads were placed on each lead and at the point where the conductor passed into the main box, RF blocking capacitors were used. A similar approach could not be used on RF signal lines, so the highest quality coaxial cabling and SMA fittings were used. This cable, 0.141" Semi-Rigid Coax, has a solid outer conductor of copper and very low leakage. This cable was slightly lossy (5.5 dB per 100 feet) but when used in short lengths the loss was insignificant. Another advantage of the 0.141" cable is its small diameter and the ease with which it could be bent to fit the confined spaces.

The only other potential source of RF leakage was in the area around the manually tunable notch filter. In order to tune it without opening the top of the deck box, it was necessary to extend its tuning shaft through the side panel of the deck box. With only the shaft protruding and the tuning dial not visible this proved to be a blind operation and, therefore, an RF blocking laminated window was installed through which the tuning dial could be seen. As physical protection for the tuning knob and this window, a metal box was hinged to the outside of the deck box and a sliding bolt provided to lock it into place. (See Figure 3) A 28 volt incandescent light was provided to illuminate the tuning dial and operated from the 36 volt power input through a dropping resistor.

E. DECK BOX II

The original design called for a single, manually tunable notch filter to be built into the deck box. Further calculations

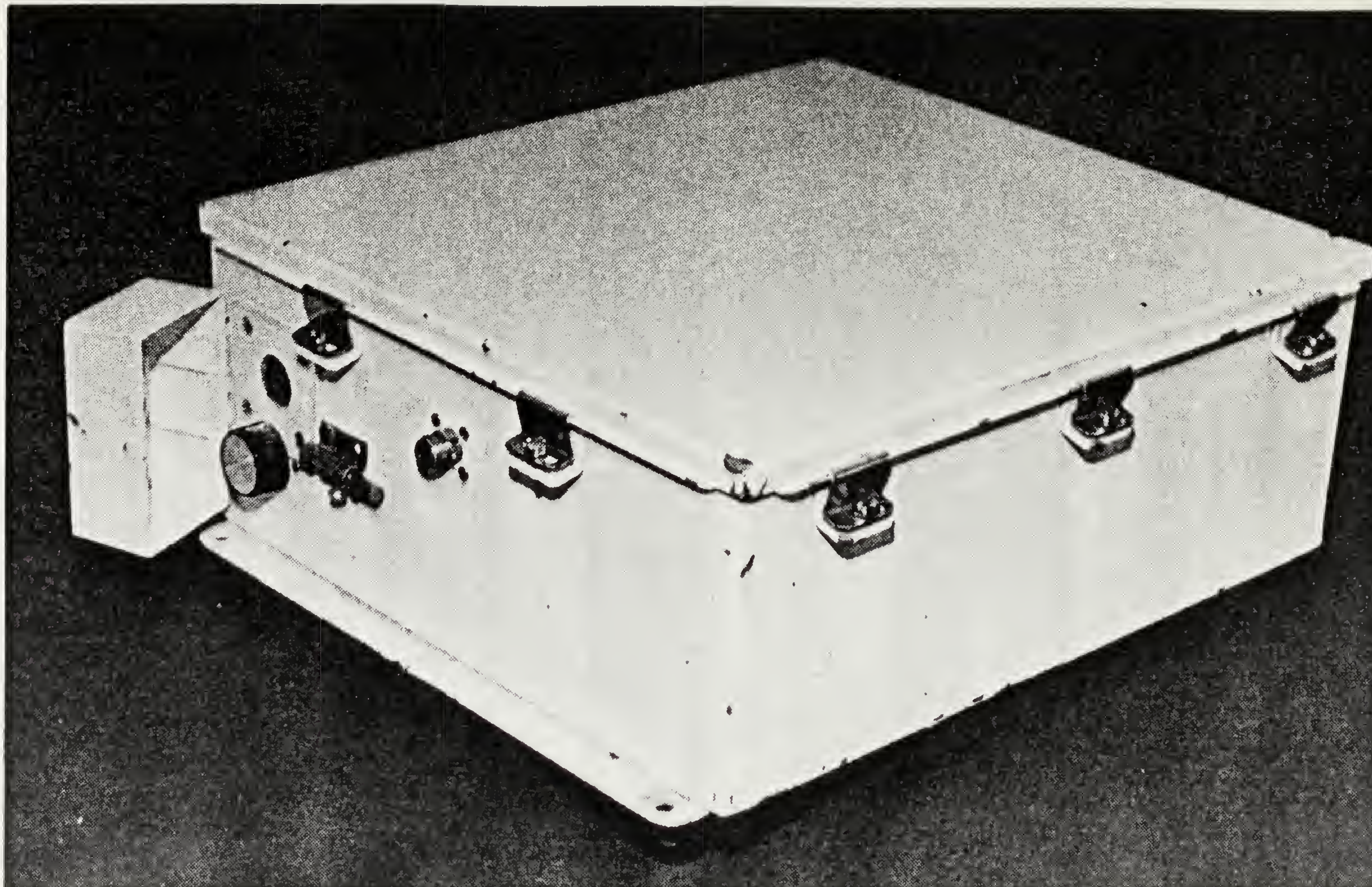

Figure 3. DECK BOX I WITH MANUAL NOTCH FILTER TUNING KNOB.

of possible near-band and in-band interferers indicated that it would be desirable to augment this initial notch filter with a second tunable notch filter and an additional tunable bandpass filter. Both notch filters offer a minimum of 20 dB of suppression to a signal over a 5 MHz bandwidth. The band-pass filter has a bandwidth of approximately 5 per cent (e.g. 15 MHz at 300 MHz). These two auxiliary filters were located in a second deck box with identical dimensions to the first. Both are remotely tunable from the main control panel using DC motors with a very high reduction ratio, thus offering high torque and low speed. The notch filter could be tuned from 200 MHz to 400 MHz in 90 seconds, while the bandpass filter covers the same range in 120 seconds. Both filters were switched into the circuit by throwing the "REMOTE CON-TROLLED FILTER OUT/IN" switch on the main control panel. The manually tuned notch filter was permanently connected into the RF circuitry and, when not in use, was tuned to 200 MHz.

Although the fixed bandpass filters allow approximately 70 dB rejection to signals $\pm$ 44 MHz from the center frequency, it was found that by using the tunable bandpass filter in con-junction with the fixed bandpass filters that interfering signals located within the passband of the fixed filter could be suppressed to an acceptable level.

The motors used to tune the remotely controllable filters receive their voltage from the main control box via the main deck box (See Figure 4). Plus or minus 12 volts DC was supplied to the main control box from the level density

analyzer. The direction of rotation was controlled by the up and down tuning switches on the front panel of the main control box. It was not possible to tune these filters electrically from the local position in the main deck box, but it was possible to control their insertion into the system. The second deck box was RF shielded from its surrounding environment utilizing a dog-box, ferrite beads, and feed-through capacitors (See Figure 4). Connections between the two deck boxes used N-type connectors and RG-214/U coaxial cable.

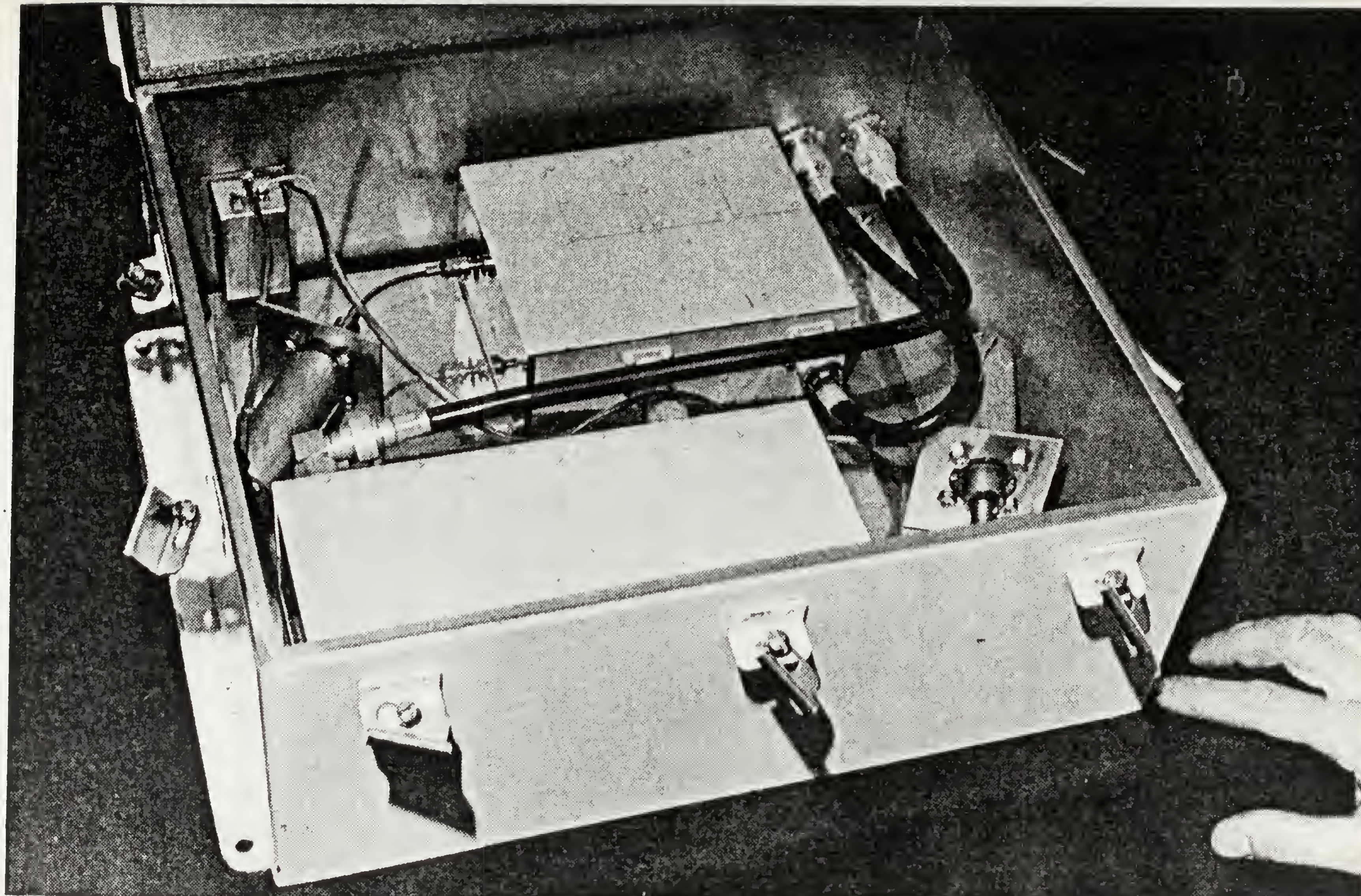

Figure 4. DECK BOX II.

V. MAIN CONTROL PANEL

A. PHYSICAL CONFIGURATION

All control functions with the exception of tuning the manual notch filter could be accomplished from the main control panel. The deck box control panel was located in the same cabinet as the digital cassette tape recorder utilized for recording the output of the level density analyzer. (See Figure 5). Most of the volume was occupied by the Acopian model B36GT230 thirty-six volt power supply. This unit was located at the right hand side of the cabinet and directly behind it was the Lambda five-volt regulator which provided power for the front panel power indicator light and the "RF Continuity" indicator when the "Panel Light Test" button was depressed.

A 110 volt AC blower motor was mounted through the back panel of the cabinet and exhausted air from around the power supply. Also located on the rear panel was a 14 pin Amphenol plug into which the deck box control cable was connected. A two ampere fuse protected the power supply and blower and an additional two ampere fuse was integral to the power supply. The power for both the control panel and the main deck box were both controlled by the front panel switch marked "POWER." The red LED immediately adjacent indicated when power had been applied to the system.

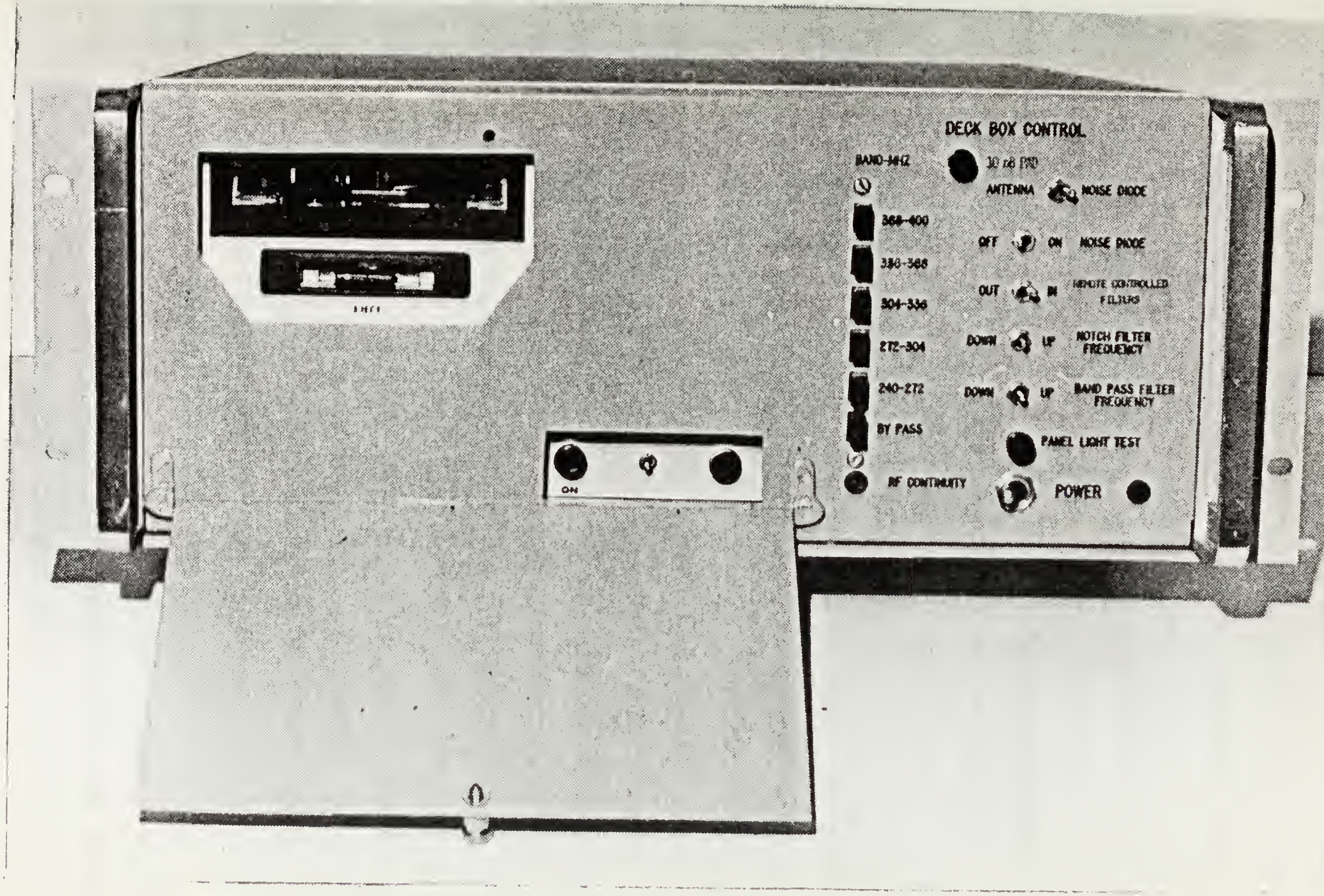

Figure 5. MAIN CONTROL PANEL, FRONT VIEW.

B. CONTROLS AND FUNCTIONS

A six-position pushbutton interlocking switch was located on the left side of the control panel and was used for fixed bandpass filter selection. The top five positions were marked to indicate the band selected and the bottom position selected the bypass around the fixed filters and the amplifier in the deck box. If the deck box was operating properly, the "RF Continuity" LED would light when any of these buttons were depressed. If it did not light, the LED itself could be tested by simply depressing the "Panel Light Test" button at the right side of the panel.

Switches were provided at the right side of the panel for selection of the other deck box functions. The top switch selected whether the input to the system was the antenna or the noise diode and controlled the appropriate SPDT coaxial switch in the deck box. The "NOISE DIODE ON/OFF" switch controlled the 28 volts applied to the noise diode via a relay in the deck box. The noise diode could only be turned on when the "ANTENNA/NOISE DIODE" switch was in the noise diode position. The "10 dB PAD" button located at the top of the control panel inserted the 10 dB attenuator into the RF circuitry of the deck box only when the "ANTENNA/NOISE DIODE" switch was in the antenna position. Both of these functions shared the same control line to the deck box. This was done for two reasons. Firstly, the number of control lines became limited when the decision to add the remotely tunable notch and bandpass filters in the second deck box was made. Secondly, with

the final configuration, it was now impossible to inadvertently leave the noise diode energized when not connected to the circuit, and more importantly impossible to have the 10 dB attenuator inserted without the operator being conscious of it. This reduced the possibility of misinterpreting signal levels.

The "REMOTE CONTROLLED FILTERS OUT/IN" switch grounds the transfer switch control line and connects the two remotely controlled filters in the second deck box into the RF circuitry. The two switches marked "NOTCH FILTER UP/DOWN" and "BANDPASS FILTER UP/DOWN" controlled the voltage applied to the DC motors which drove the two filters in the second deck box. Direction reversal was accomplished by having a common ground and applying either plus or minus 12 volts DC to the motors. In this way only two control lines were required for the two filters. The plus and minus 12 volts DC were supplied by the power supply in the level density analyzer. Therefore, the power to the level density analyzer must be turned on before the filters can be tuned in frequency.

C. CONTROL CABLE

The control cable consisted of a nine pair, 18 conductor cable having an overall shield. Each conductor is a solid 22 gauge wire and in long lengths represents moderate ohmic losses. The only significant voltage drop in the system was the 36 volt dc power applied to the deck box. Therefore, three conductors were paralleled to supply this current and three more paralleled for the common ground. This reduced

the number of conductors to 14 which were connected to the 14 pin Amphenol weatherproof plugs at the deck box and control box ends of the cable (See Figure 6).

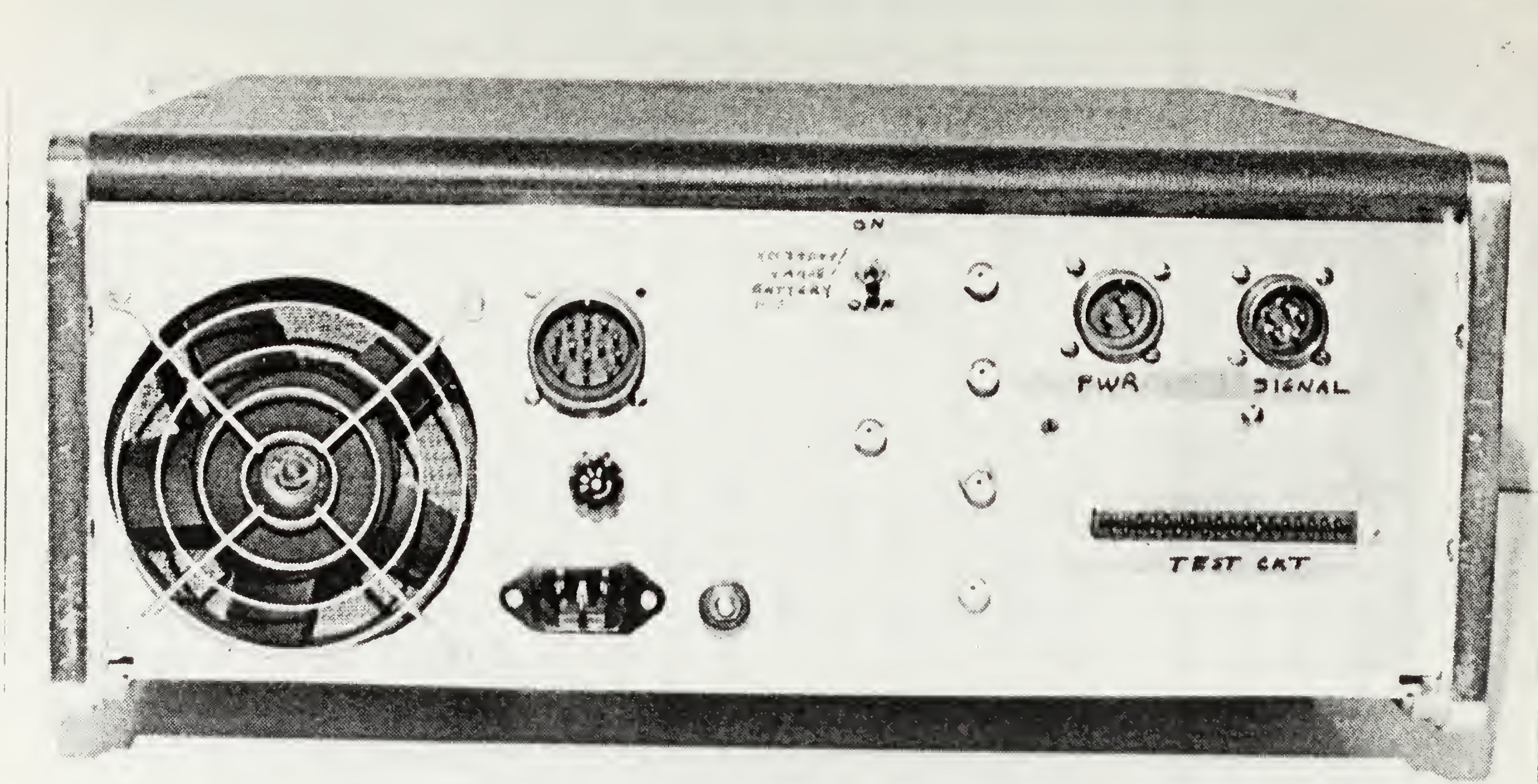

Figure 6. MAIN CONTROL BOX, REAR VIEW.

VI. ANTENNA AND DECK BOX PLATFORM

When completed and after undergoing laboratory testing, the two deck boxes were mounted on a one-half inch aluminum plate measuring 24 x 27.5 inches. In the center of this plate was heliarced a four-inch aluminum tube which acted as a support for the log periodic helical antenna used in the system. (See Figure 7).

The antenna, a model 3101 built by EMCO, Inc., was rotatable through 360 degrees in the horizontal plane and could be tilted in elevation from 80 degrees above the horizon to 85 degrees below the horizon. In this manner the antenna, deck boxes and base plate could be tied to the deck as one integral unit utilizing eyebolts on the baseplate. The antenna came with a mounting socket that was judged structurally weak for the rolling and pitching environment in which it was to be used. Therefore, a specially designed phenolic antenna base was constructed. The entire antenna mount and deck box unit proved to be structurally sound during testing at sea.

As further protection against rain and salt spray, canvas bags were sewn to cover each deck box individually. When cables were assembled, silicone grease was used on the internal workings of all exposed RF connectors and all connectors were wrapped in black electrical tape and sprayed with a clear plastic spray to further protect them from moisture. This procedure, when rigidly followed, relieved all worries of incorrect measurements due to wet or dirty connections.

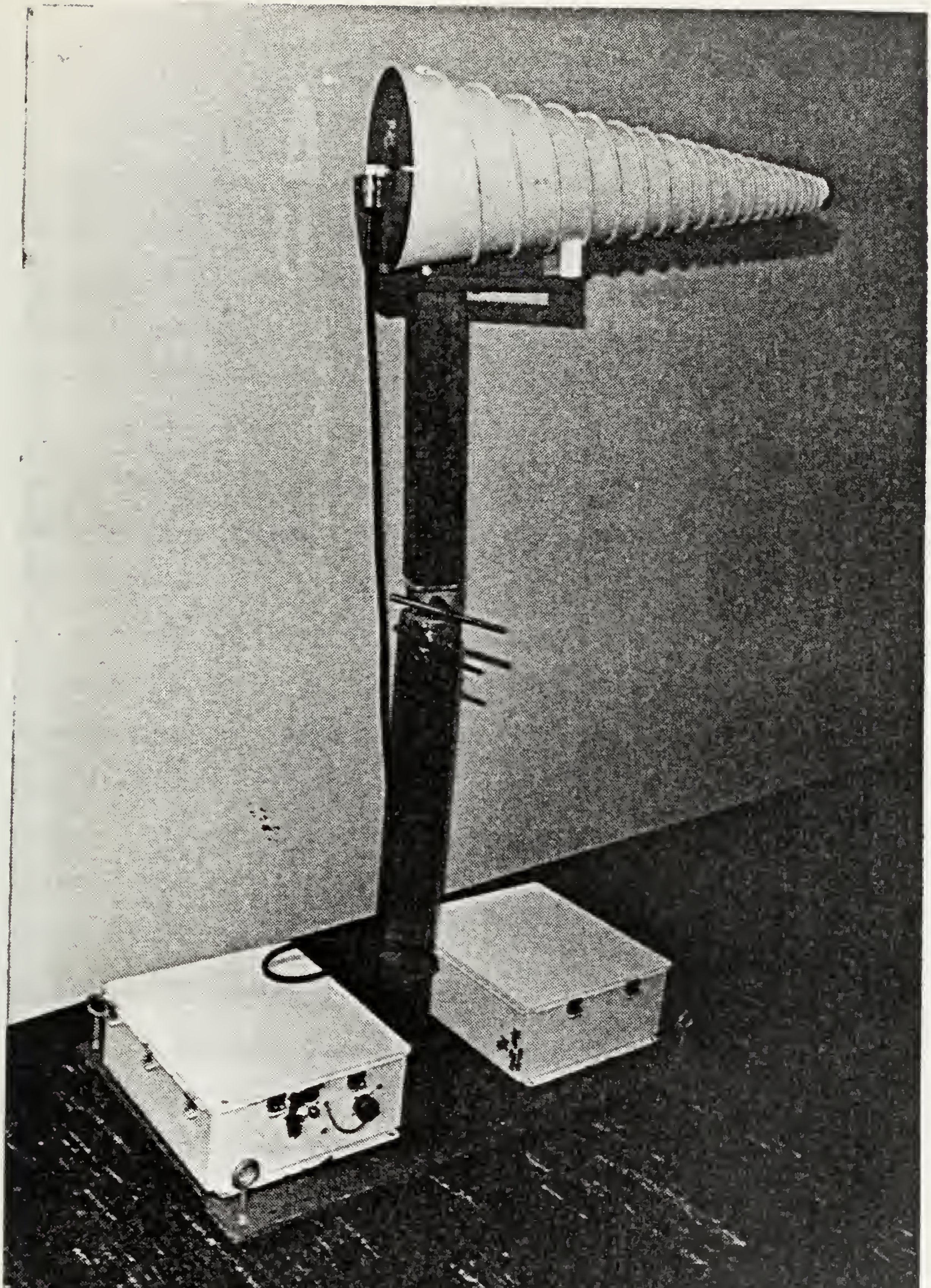

Figure 7. DECK BOXES AND ANTENNA.

VII. SYSTEM INTEGRATION

A. COMPATABILITY

The deck boxes and control panel were designed to be compatible with other units constructed in the RFI test package. As mentioned previously, the deck box control panel and the digital tape recorder shared the same cabinet (See Figure 5). The 36 volt power supply in the control unit was used to charge the standby battery pack for the digital tape recorder. The level density analyzer interfaces with the deck box by supplying the plus and minus twelve volts necessary to drive the motors in the second deck box.

Care was taken in the design and construction of all units so as not to interfere or degrade the performance of any other unit by poor engineering practices. All potential conflicts were discussed at weekly meetings amongst all personnel involved. The results of this extra effort was a well-integrated test system, well thought out in all areas and taking into account human engineering, ease of operation and repair.

B. TECHNICAL SUPPORT

Before the deck boxes and main control box were released for shipboard testing, a complete parts support package containing all necessary and critical spares was assembled. (See Appendix B). In addition, complete troubleshooting instructions were written (See Appendix C) and schematic diagrams drawn (See Appendix A). This, together with a functional block diagram and detailed operation instructions,

comprised a fully documented and supported system ready for deployment and extended field use.

VIII. CONCLUSION

The completed deck box assembly and deck box control panel fulfilled all of the requirements originally placed upon them. They proved themselves to be a versatile combination of devices offering many different modes of operation and at the same time being straightforward in operation. Their reliability during shipboard testing was outstanding with the only recorded failure being the incandescent bulb illuminating the manually tunable notch filter during sea trials aboard the research vessel ACANIA. If a second unit were to be constructed, it would be recommended that it be nearly identical in configuration with only a few minor changes in component layout. Consideration should be given to incorporating both deck boxes into a single larger box and to remotely tune the notch filter which is currently manually tuned.

APPENDIX A

14 PIN AMPHENOL PLUG ON DECK BOX CONTROL

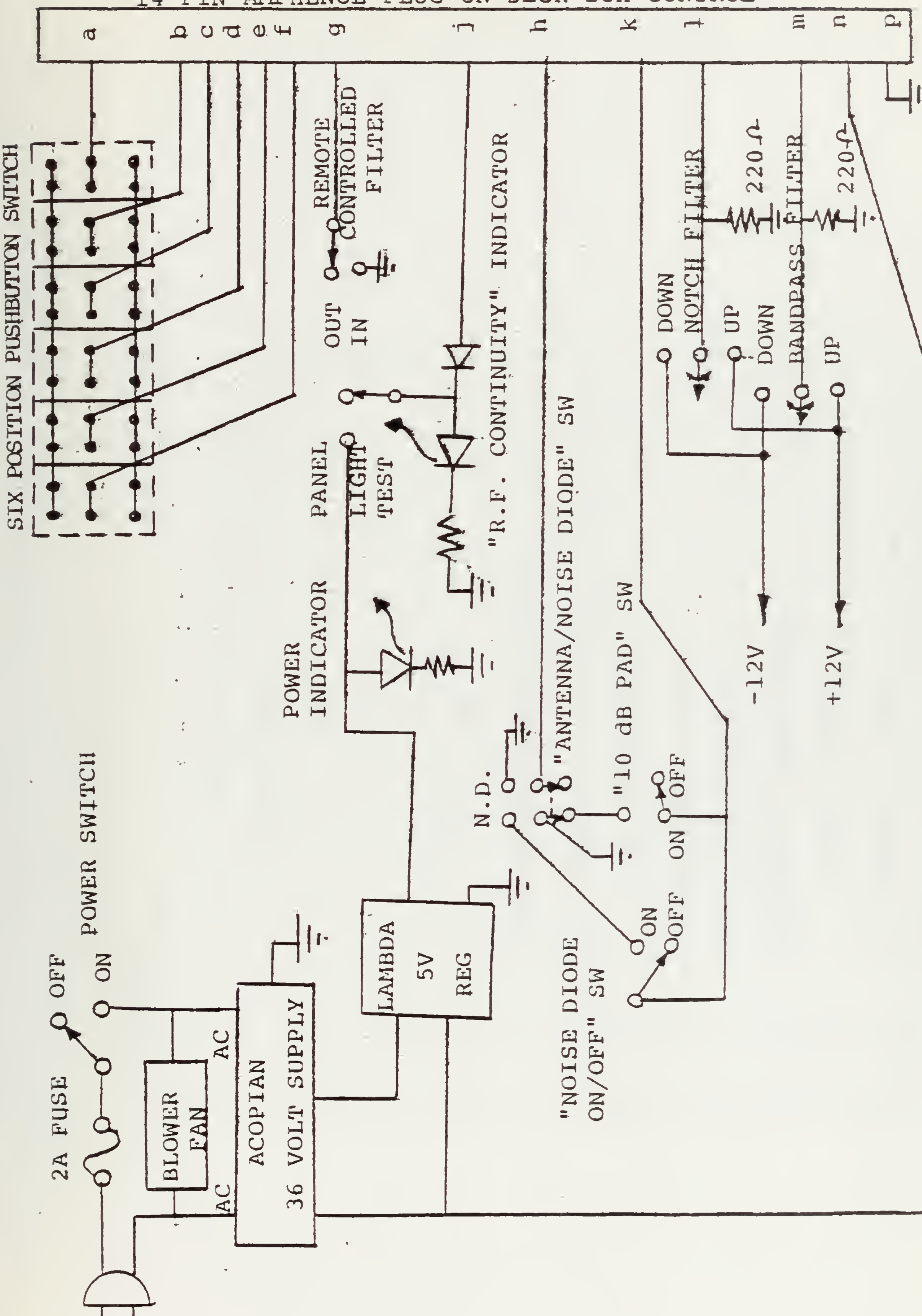

Figure 1. DECK BOX CONTROL PANEL WIRING

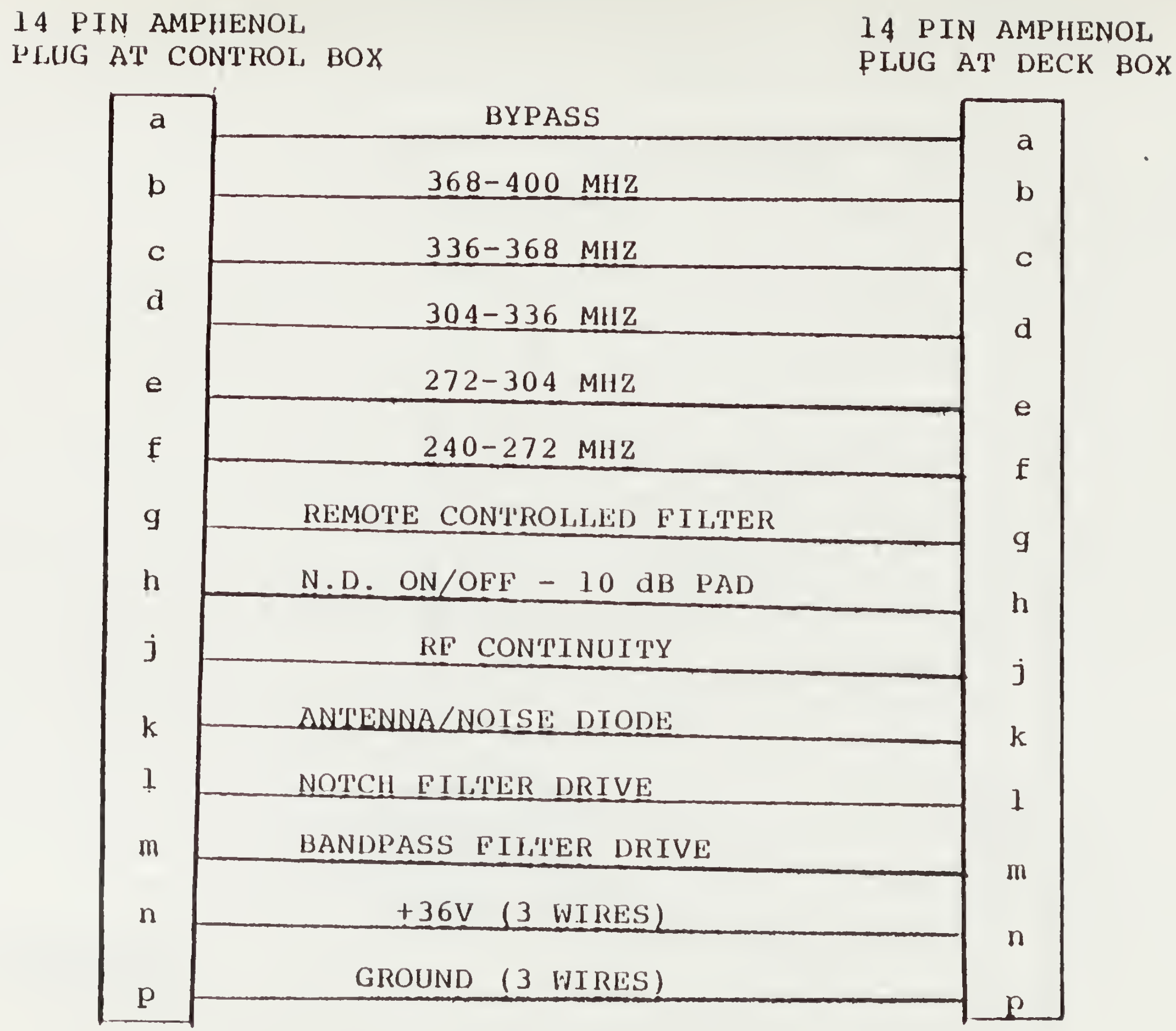

Figure 2. DECK BOX CONTROL CABLE

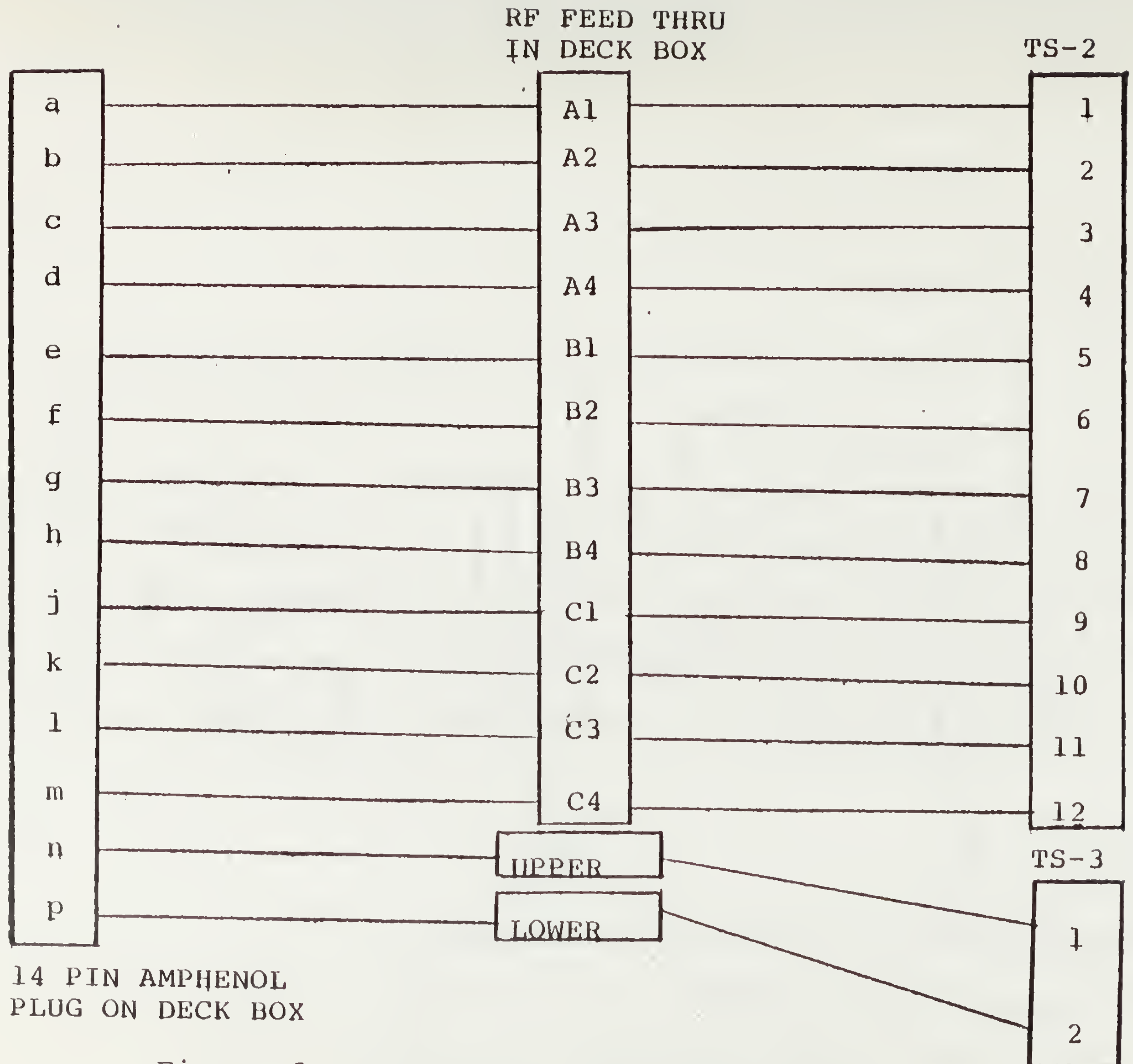

Figure 3. DECK BOX I INTERCONNECTIONS

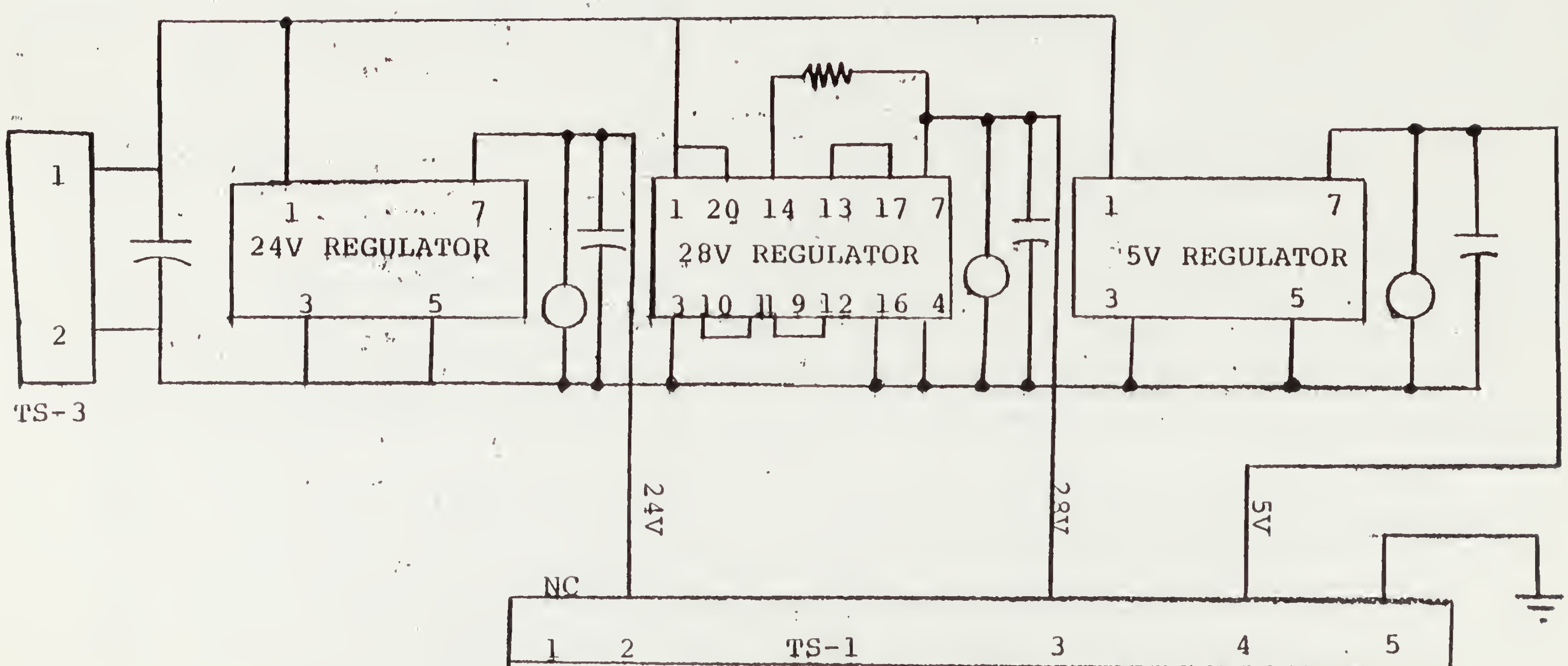

Figure 4. DECK BOX I POWER SUPPLY

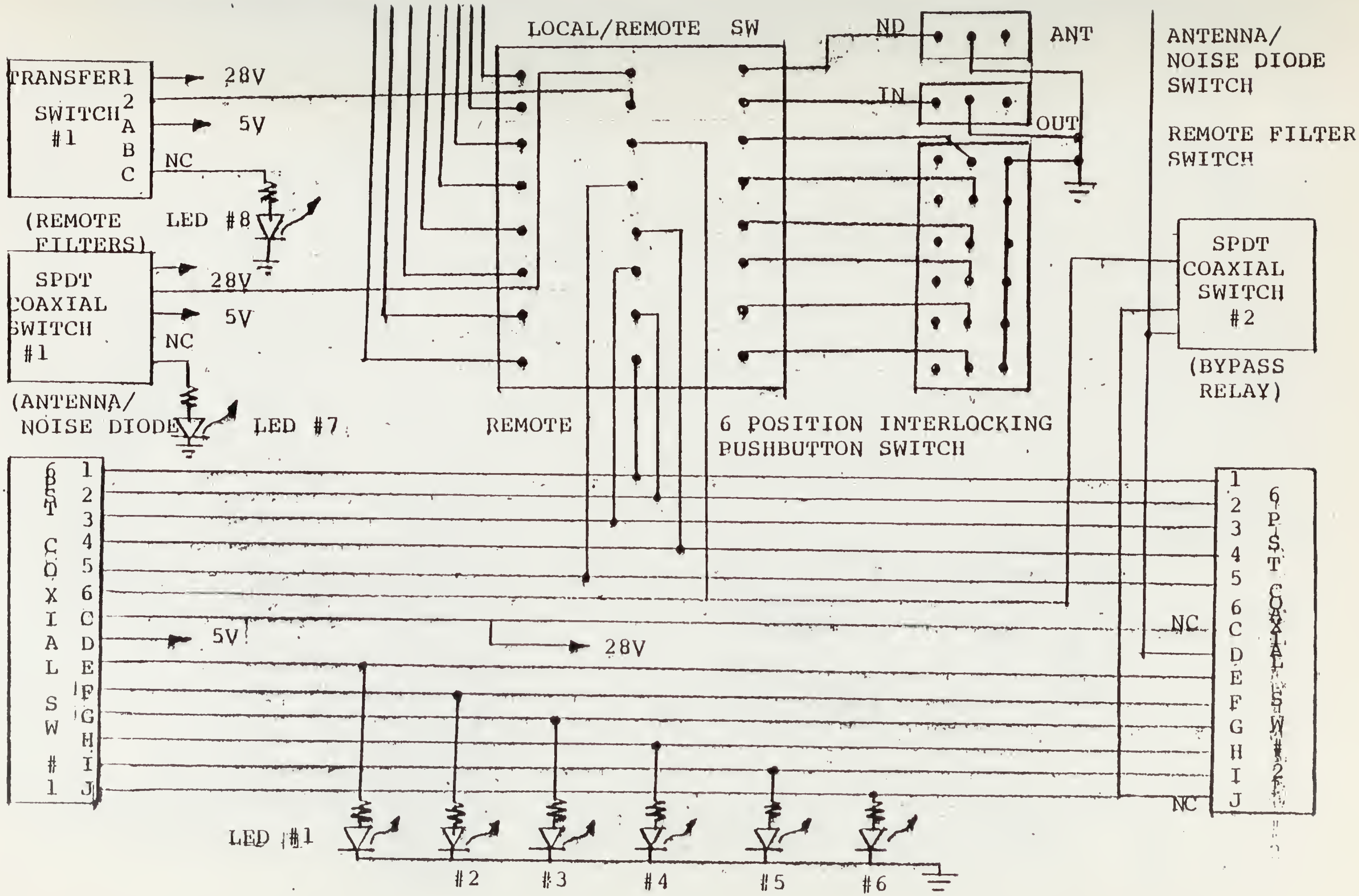

Figure 6. DECK BOX I WIRING DIAGRAM

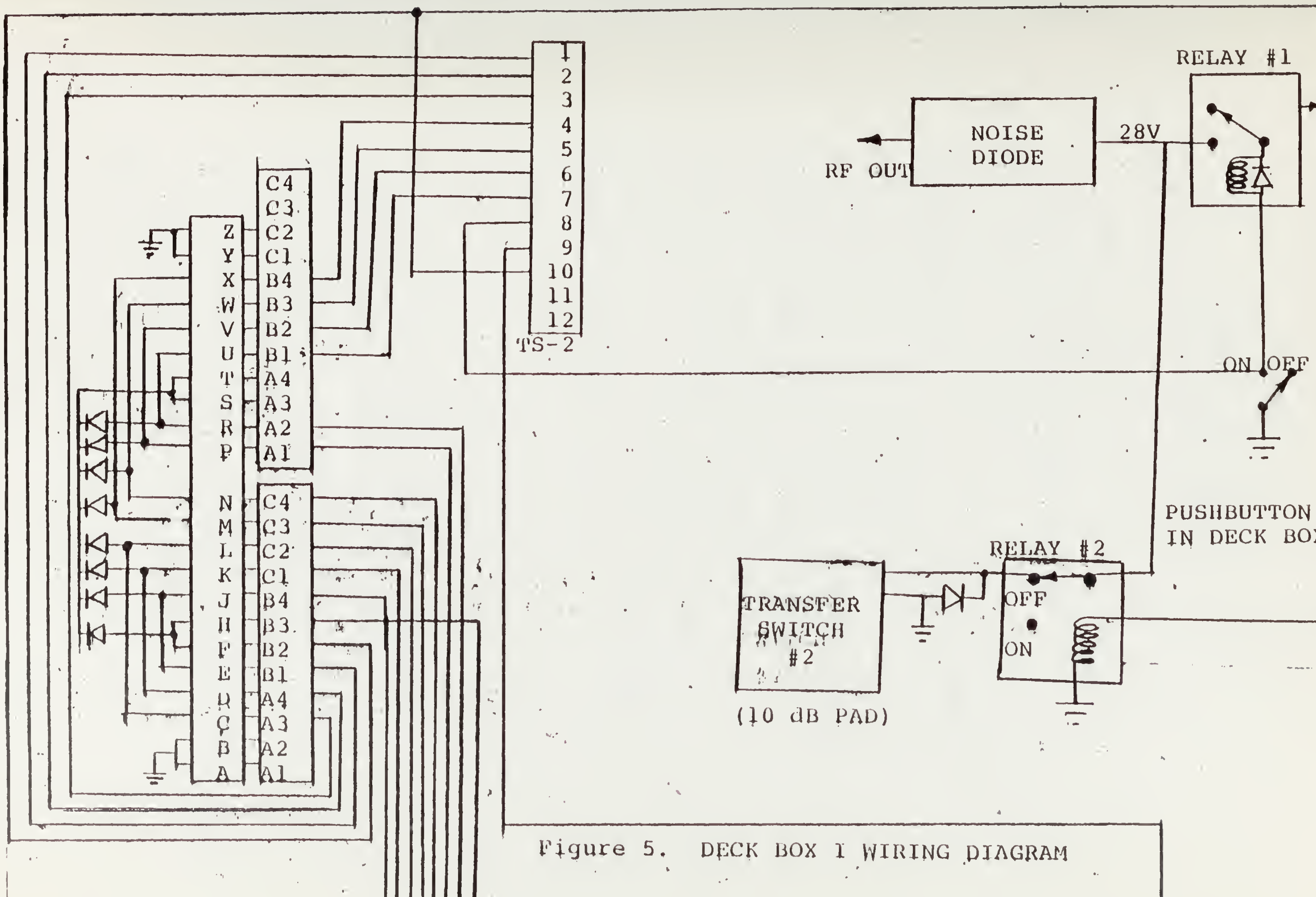

Figure 5. DECK BOX I WIRING DIAGRAM

APPENDIX B

SPARE PARTS LIST

CONTROL BOX

QTY	DESCRIPTION
1	Acopian 36V Power Supply VB36GT290
10	Buss AGC2-2 Amp Fuse
1	Switchcraft 6 Position Interlocking Switch P.N.-100-75-15
1	Master Power Switch M535058-23
2	Alco DPDT Momentary Switch MJT-105G (7510)
1	Cuttler-Hammer SPDT Pushbutton Switch
1	C & K U21 DPDT Toggle Switch
1	Cuttler-Hammer DPDT Toggle Switch
2	Alco SPDT Toggle Switch MST 1050 (7508)
1	Lambda 5V Regulator-LAS 2105

DECK BOX I

1	Teledyne 6PST Coaxial Switch CS-38516-1
1	Teledyne SPDT Coaxial Switch CS-3351C
1	Teledyne Transfer Coaxial Switch CS-3751C
1	Ailtech Noise Diode (In Box)
2	Omni-Spectra Bulkhead N-Female to SMA-Female 21011
1	10 dB Pad with Plumbing Attached
1	AEL Mic 3175-1 Limiter
1	Optimax AH-4094-8178 Amplifier

DECK BOX I (Cont'd)

1	Texscan 10BE 256/38-KK Filter
1	Texscan 10BE 288/38-KK Filter
1	Texscan 10BE 320/38-KK Filter
1	Texscan 10BE 352/38-KK Filter
1	Texscan 10BE 384/38-KK Filter
1	Amphenol 14 Pin Bulkhead Connector
1	Amphenol Protection Cap for Above 9760-22
1	Erie 12 Pin RFI Feedthru 1212-502
3	Erie Single RFI Feedthru
1	Lambda 28 Volt Regulator-LAS2228
1	Lambda 24V Regulator-LAS2124
1	Lambda 5V Regulator-LAS2105 (also used in control Box)
1	Acopian 28V Overvoltage Protector 28P25
1	Acopian 24V Overvoltage Protector 24P25
1	Acopian 5V Overvoltage Protector 5P25
3	Rayrex 220uF 5V Capacitor CE02W
3	Switchcraft 6 Position Interlocking Switch 100-75-15
1	T-Bar 8PDT Switch with Connectors 902/8C
2	Leach 28 Volt Relays (002)
2	C & K DPDT Toggle Switches (U21)
6	1819 Pilot Lights
1	1500 ufd 50 VDC Electrolytic Capacitor
6	90° .141 Cable Fittings
6	Straight .141 Cable Fittings

DECK BOX II

1	N Female to N Female Bulkhead (UG30E)
1	K & L Tunable Notch Filter
2	DC Drive Motors (C-5A-1106)

APPENDIX C

TROUBLESHOOTING PROCEDURES

A. FRONT PANEL POWER LIGHT FAILS TO LIGHT

1. Check to see that Deck Control box is plugged into 110V 60 cycle power receptacle.

2. Check 2 amp (AGC-2) fuse on back panel.

3. Remove Deck Box Control cable from rear connector. If problem remains go to Step 4; if not, go to Step 6.

4. If blower fan is running, but power light does not light and "RF Continuity" light does not light when "Panel Light Test" switch is depressed, the problem lies within the 36 Volt Acopian Power Supply. Remove top cover of unit and check fuse on back of power supply (2A Slow Blow). If fuse is good, turn on AC power (fan will run) and check for +36V from power supply. If not present, secure power, remove "+OUT" and "-OUT" terminals, and repeat above. Check fuse again. If good, replace power supply.

5. Upon re-assembly, the "Power" light on front panel should come on. Replace "Deck Box Control Cable" to rear panel and commence operation.

6. If front panel Power light comes on when "Deck Box Control Cable" is removed a short is indicated within the cable or the deck box. Check cable pin to pin using ohm meter as this is the most likely fault.

B. R.F. CONTINUTIY LED FAILS TO LIGHT

1. Depress "Panel Light Test" button on front panel.

If the light fails to come on the LED has failed. Note: "RF Continuity" light will not come on unless one of the six filter selector/bypass buttons is depressed.

2. If the "R.F. Continuity" light came on when tested, but does not light in one or all of the six above mentioned positions, the fault probably lies in the Deck Box itself. If this is the case, proceed to the deck box, open top cover, switch "Local/Remote" switch to "Local" and try each of the six positions. The corresponding LED's should light; if not, one of the two six-position coaxial switches is at fault. To determine which, go to the deck box disassembly directions and proceed. If all positions light as expected in the "Local" position test, the fault lies in the "Deck Box Control Cable" and all cables in use should be tested pin for pin for an open circuit. Be sure to return "Local/Remote" switch to "Remote" position before closing the deck box.

C. ANTENNA/NOISE DIODE SWITCH NOT FUNCTIONING

1. If it is suspected that the Antenna/Noise Diode Switch is not working, perform this simple test. In Antenna Position, tune in a signal "off the air" in any filter or bypass position and observe on the Spectrum Analyzer. Switch to Noise Diode; if the switch is working, your signal will disappear and only white noise will be present.

2. If the signal above did not disappear, the SPDT coaxial switch #1 may be defective. Test by proceeding to the deck box, opening top cover, switching "Local/Remote" switch to "Local" and turning "Antenna/Noise Diode" switch

to "Noise Diode." An audible click should be heard and the LED next to it light. If not, the switch is defective and will have to be replaced, or the "Deck Box Control Cable" may be defective. Test the cable by using an ohmmeter to find an open circuit. A quick test of the relay is to apply a ground to pin (10) of the long terminal strip (TS-2). If the relay clicks and LED lights, the relay is OK and the cable or "Antenna/Noise Diode" switch on front panel are defective. Test both.

D. NOISE DIODE DOES NOT OPERATE

Note: The "Noise Diode ON-OFF" switch only works when the "Antenna/Noise Diode" switch is in the "Noise Diode" position. Also, the noise diode output will not be observable on the spectrum analyzer unless the filter selector switch is to one of the filter positions and not in the Bypass position.

1. Check to see that one of the filters is selected and that the "RF continuity" lamp is on. Tune the spectrum analyzer to a center frequency at the midpoint of the selected band, and set the spectrum analyzer scan width to 5 MHz per division. Turn the "Antenna/Noise Diode" switch to "Noise Diode" (any signals present should disappear). Observing Spectrum Analyzer switch "Noise Diode ON-OFF" switch to "ON." The noise on the spectrum analyzer display should increase by approximately 10 dB throughout the band selected. If not, a fault in the "Noise Diode power relay," (Relay #2 located in heart of Deck Box), the "Deck Box Control Cable" or the front panel "Noise Diode OFF-ON" switch may be indicated. A quick

check of the "Noise Diode ON-OFF" switch may be made by grounding temporarily the center pin which has the blue wires to it. If this solves the problem replace the switch. If not, proceed to deck box, open top cover, switch to "LOCAL" position and push small red pushbutton. An audible click should be heard; if not, the power relay (Relay #1) is defective. If a click is heard but the noise diode is not operating, remove its power connection (BNC fitting at end) and check for +28V DC. If relay clicks, but voltage is not present, the 28V voltage regulator in the deck box has failed. Replace with a spare.

2. If the Noise Diode Power relay works in the "LOCAL" Position but not in "REMOTE" a failure of the "Deck Box Control Cable" is indicated. Test cable pin for pin looking for an open circuit. Confirmation of this fault may be made by having the "ANTENNA/NOISE DIODE" switch in the "Noise Diode" position, the "LOCAL/REMOTE" switch in "REMOTE" and temporarily grounding pin (8) of the 12 pin terminal strip (TS-2) inside the deck box.

E. 10 DB PAD APPEARS NOT TO WORK

Note: The 10 dB Pad can only be inserted in the RF circuit when the "ANTENNA/NOISE DIODE" switch is in the "ANTENNA" position.

1. Test to see if 10 dB Pad is being inserted by tuning a signal "off the air" and displaying it on the spectrum analyzer. This is most easily done in the"BYPASS" position. With the "ANTENNA/NOISE DIODE" switch in the "ANTENNA" position

depress the "10 dB Pad" Pushbutton switch on the front panel. If the circuit is operating properly, the display on the spectrum analyzer will decrease by 10 dB. If not, proceed with the following steps.

2. Proceed to Deck Box, open top cover, switch to "LOCAL" position, turn "ANTENNA/NOISE DIODE" switch to "ANTENNA" and depress small red momentary button. If an audible relay click is heard the relay is functioning and the front panel "10 dB Pad" switch is defective or the "Deck Box Control Cable" is bad. Test the cable. A quick test to see that relay is OK is to switch to "REMOTE," making sure Deck Box Control Switch is on "ANTENNA" position and then grounding pin 10 of the 12-pin terminal strip in deck box (marked TS-2). If the 10 dB PAD is now in the circuit, the front panel pushbutton switch or the control cable is bad.

3. Before closing Deck Box be sure "LOCAL/REMOTE" switch is returned to "REMOTE" position

F. TROUBLESHOOTING DECK BOX II CIRCUITS

Note: It is expected that operators will think a fault exists in this circuit, yet in actuality the circuit will be operating properly. The problem arises from the fact that a notch filter and bandpass filter are inserted into the circuitry when the "Remote Controlled Filter" switch is thrown to "IN." The difficulty is that neither the notch nor the passband can be seen unless they are tuned to the same frequency range as the spectrum analyzer and the fixed band-pass filter being selected.

1. If it is suspected that the Remote Tunable Filters are not moving in accordance with the setting on the front panel try the following procedure. Tune in a known signal in the "ANTENNA" position of the "ANTENNA/NOISE DIODE" switch. Observe its display on the spectrum analyzer. Now switch "IN" the "REMOTE CONTROLLED FILTERS" and see if the signal disappears. If so, the transfer switch is working, and the next step is to tune the Bandpass Filter using the "UP/DOWN BANDPASS FILTER SWITCH."

Turn on the noise diode after placing the "ANTENNA/NOISE DIODE" switch in the "NOISE DIODE" position. Sequentially step thru the five fixed bandpass filters while observing the spectrum analyzer. When the fixed bandpass filter and the tunable bandpass filter coincide in frequency the output of the noise diode will be seen to be approximately 10 dB above the background noise.

2. Once you have located the Bandpass Filter, it's time to find the Notch Filter and tune it. Begin by switching to the "NOISE DIODE" position and tuning the Noise Diode "ON." This will give you approximately 10 dB of additional noise to look at on the spectrum analyzer. While observing the output of step one above, begin moving the NOTCH FILTER "UP" or "DOWN." Sometime in the next minute and a half a small notch should march across your noise. Watch very closely as it is easy to miss.

G. DISASSEMBLY OF DECK BOX I

Note: Due to the complexity of the circuitry and its limited space, the assembly of Deck Box I is complex and must be done in an orderly manner. By following the steps listed below, no difficulty should be experienced in assembling or disassembling the deck box.

1. If the problems encountered in operation of the deck box can not be corrected by following the accompanying directions, it may be necessary to disassemble the deck box. It is to be emphasized that all troubleshooting tricks should be employed and it should be definitely determined that an inner component of the deck box is faulty before any disassembly is attempted. Due to the complexity of the assembly it is expected that two hours of assembly and disassembly time will be consumed in simply looking around. So, be sure your problem lies inside the deck box.

2. It is best to remove the deck box from its antenna platform and place it on a well lighted test bench. As a final cable check, hook the Deck Control Box to the Deck Box using the short length of cable and see if you still have the problem. If so, proceed. All directions will be given for the box positioned in front of you with the hinge of the top facing away from you.

3. Open the top cover. Remove both ends of the two flexible RF cables crossing over the Tunable Notch Filter. Next prepare the Notch Filter for removal. It is held down with 4 screws and will require complete disassembly of its

RF plumbing before the filter can be removed. Loosen the set screws on the tuning shaft. Remove the filter.

4. Remove the RF plumbing that connects to the RF "IN" and "OUT" at the left and right ends of the box. Do not attempt to remove both ends as this is not necessary and may prove difficult.

5. Remove the terminal lugs from the two screw terminal strips (TS-1 & TS-2). The top strip is the power connections, (TS-1) and the bottom comes from the Deck Box Control Cable Dog Box (TS-2). Bend the Deck Box Control Cable harness over the lip of the box so that it will not be in the way when the large bottom chassis is removed.

6. In the upper left hand corner of the box is located the pilot light for the Notch Filter dial. Remove it by taking the nut off the stud that holds it. Route wires out of the way.

7. In the upper right hand corner are a red and blue wire running from the Dog Box to a terminal strip on the main chassis. Remove them.

8. In the four corners of the main chassis are four screws. Remove them. The main chassis is now ready for removal. Carefully hold the main chassis by whatever means is comfortable and lift the front edge (one nearest you) out of the box first with a rocking motion. If you have removed everything as directed the whole assembly will come out very easily.

9. Set the deck box aside and place the chassis in front of you as aligned before. In order to get inside the control

box it will first be necessary to remove the RF fittings from the five tubular Band Pass Filters located below it. (Note: It is only necessary to remove the lower end, and the torque wrench should be used for reassembly).

10. There are four small screws located on the lips of the control box. Remove them using a long-narrow screwdriver. When this is done, the control box can be lifted away from the main chassis. If one of the Texscan tubular Bandpass filters needs replacing, remove the aluminum plate covering them, the foam sheet, and make the necessary replacement. On reassembly, assure that the filters are in the correct order with the highest frequency furthest way and the lowest frequency nearest the edge of the chassis.

11. In order to troubleshoot the interior of the control box, consult the schematic diagram. Care must be exercised that when following wire you not become confused.

12. Reassembly is performed exactly as disassembly only in reverse. Follow the directions exactly.

H. DISASSEMBLY OF DECK BOX II

1. Deck Box II is relatively simple in comparison with Deck Box I. All components are readily accessible and only a few minutes are required for disassembly and reassembly.

2. RF is sent to this box via the two RF cables interconnecting the two Deck Boxes. These are the most likely sources of trouble and should be suspect first. They can be checked by disconnecting the RF cables inside Deck Box II and using a short jumper cable to short them. If the "Remote

Controlled Filter" switch on the Deck Box Control panel is switched "IN" and "OUT" no appreciable difference in signal displayed on the spectrum analyzer should be seen. If the cables are defective, a noticeable change will be seen.

3. If upon opening Deck Box II it is ascertained that the RF cables are OK, the motors are driving the filters but still the output is wrong, it is possible that either the "Tunable Bandpass or Notch Filters" may be defective. The notch filter is removed by taking out four screws. To remove the bandpass filter it is necessary to first remove the entire chassis and then remove the screws from below.

4. If it is determined that the filters are not being driven by the motors, first determine if the necessary +12 and -12V DC voltages are being applied. (In reality these voltages may be as low as $\pm$8V DC depending on control cable length). If the voltages are present replace the motor after first checking it for operation in both directions by changing the polarity of the applied voltage.

LIST OF REFERENCES

1. Shuff, A.R. and Ohlson, J.E., "An Instrumentation Package for Measurement of Shipboard RFI", Technical Report, Naval Postgraduate School, Monterey, California, in preparation, 1976.

2. Mace, F. E. and Ohlson, J.E., "A High Level Noise Blanker and RF Amplifier System for the UHF Band," Technical Report, Naval Postgraduate School, Monterey, California, in preparation,1976.

3. Arneson, D. C. and Ohlson, J.E., "A Level Density Analyzer for Shipboard RFI Measurements," Technical Report, Naval Postgraduate School, Monterey, California, in preparation, 1976.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Library, Code 0212 Naval Postgraduate School Monterey, California 93940	2
2.	Professor Donald E. Kirk, Code 62 Naval Postgraduate School Monterey, California 93940	1
3.	Associate Professor John E. Ohlson, Code 620L Naval Postgraduate School Monterey, California 93940	1
4.	LT Gary B. Parker, USN Rt. 11, Box 373D Olympia, Washington 98102	1

Thesis 165814
P1585 Parker
c.1 Deck boxes for UHF
SATCOM frequency inter-
ference study.